

WERNER'S CO-ORDINATION THEORY

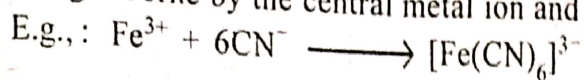
Alfred Werner in 1893 put forward his famous co-ordination theory to represent the structure of complex compounds such as $\text{CoCl}_3 \cdot 6\text{NH}_3$, $\text{K}_4[\text{Fe}(\text{CN})_6]$ etc. The fundamental postulates of this theory are summarised as follows:

1. There is a central metal atom around which other atoms or groups are arranged or co-ordinated. Neutral molecules or oppositely charged ions are co-ordinated to the central atom.
2. The maximum number of atoms or groups which can be co-ordinated to a central metal ion or atom is known as its co-ordination number [CN]. The co-ordinated groups are called ligands.
3. Each metal has a fixed CN.
4. Metal possess two types of valencies.
 - a) Primary or ionisable valency.
 - b) Secondary or non-ionisable valency.

Primary valency corresponds to the oxidation state of the metal. It is always satisfied by negative ions.

Secondary valency corresponds to the CN of the metal. It is satisfied by negative groups or neutral molecules or even by positive groups.
5. The sphere enclosing the central metal ion and the co-ordinated groups is called the **co-ordination sphere**.
6. The secondary valencies are directed in space about the central metal ion. Thus for metals with C.N. 6 the six ligands are arranged at the six corners of a regular octahedron with the metal ion at its centre. For metals with co-ordination number 4, four such ligands may arranged either in square planar or tetrahedral fashion.
The complex compounds are capable of exhibiting the phenomenon of isomerism.
7. Every element tends to satisfy both its primary and secondary valencies. To meet this requirement a negative ion often shows a dual behaviour, i.e., it may satisfy both primary and secondary valencies.

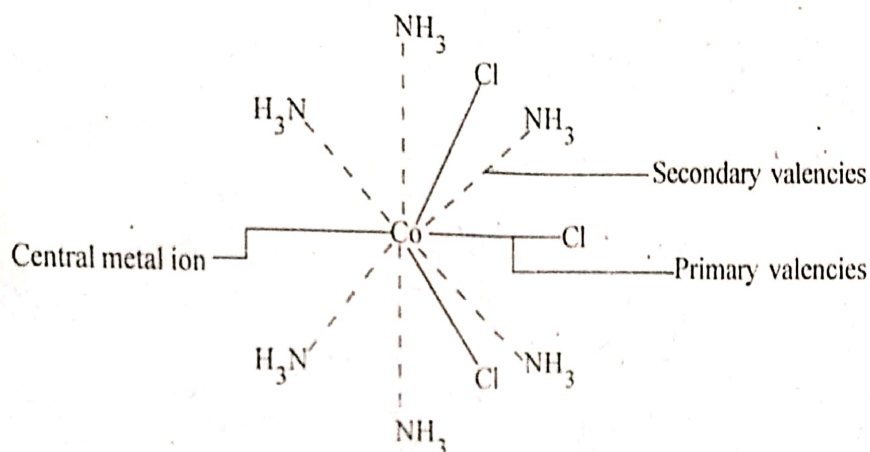
8. The net charge on the co-ordination complex is the resultant of the charges borne by the central metal ion and the ligands.



Applications :

On the basis this theory, Werner assigned the following structure to $\text{CoCl}_3 \cdot 6\text{NH}_3$ representing primary valencies with solid lines and secondary valencies with dotted lines.

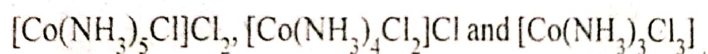
The primary valency (i.e., oxidation state of +3) is satisfied by three Cl^- ions as shown by solid lines and are kept outside the co-ordination sphere. As all the three Cl^- ions are loosely bound, they are immediately precipitated as AgCl on the addition of AgNO_3 solution.



Treatment with HCl at 100°C effects no removal of ammonia. This shows that all the six ammonia molecules are unionisable and are held to the metal ion in the co-ordination sphere. Werner formulated this complex as $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$.

Others examples :

$\text{CoCl}_3 \cdot 5\text{NH}_3$, $\text{CoCl}_3 \cdot 4\text{NH}_3$ and $\text{CoCl}_3 \cdot 3\text{NH}_3$ may be written as follows:



In the molecule $\text{CoCl}_3 \cdot 5\text{NH}_3$ which is formulated as $[\text{Co}(\text{NH}_3)_5\text{Cl}_2]$ one Cl^- ion does the dual functions, since it satisfies both primary and secondary valencies. This Cl^- ion being nonionic is not precipitated as AgCl by Ag^+ ions. Hence it is placed along with five NH_3 molecules and central metal ion in the co-ordination sphere. The other two Cl^- ions being ionic are precipitated as AgCl by Ag^+ ions.

The molecule $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ contains only one Cl^- ion which gets precipitated as AgCl by AgNO_3 solution.

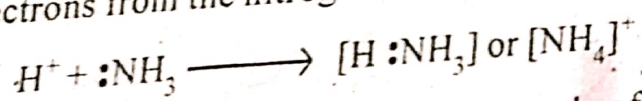
The molecule $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ has no ionic Cl^- ion and hence is behaves as a non-electrolyte.

II. SIDGEWICK THEORY (Effective Atomic Number Theory)

- i. Complexes are formed by donation of an electron pair from the ligand to the metal or metal ion.
- ii. The metal ion will continue to accept electrons till the total number of electrons in the metal or metal ion and those donated by ligands is equal to the atomic number of the inert gas which follows the central metal in the periodic table.

Explanation :

In the formation of complexes, saturated molecules or ions take part. This suggests the operation of dative or co-ordinate covalency. In the formation of the ammonium radical, a proton accepts and shares a pair of electrons from the nitrogen atom of a saturated ammonia molecule.



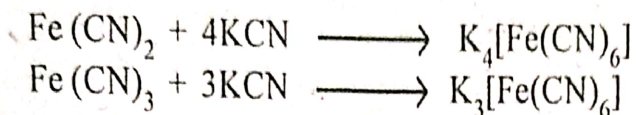
Similarly, a cobaltic ion plays the role of an acceptor which receives and shares 6 pairs of electrons from 6 NH_3 molecules.

A fresh shell of electrons is thus formed around the cobaltic ion. This shell now consists of 12 electrons. This is also a stable grouping.

The cobaltic ion (2, 8, 14), accepts these 12 electrons. So it attains a structure 2, 8, 14 and 12. All the electrons in the last shell are shared. the total number of electrons now belonging to cobalt is 36. This is the number for the inert gas krypton.

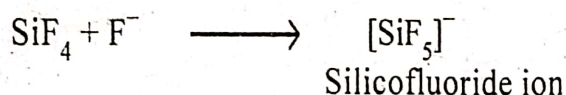
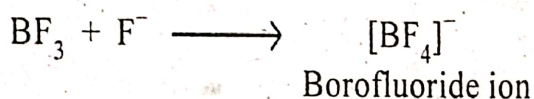
The NH_3 molecules in the $[\text{Co}(\text{NH}_3)_6]^{3+}$ may be replaced by H_2O molecules one by one till a hexa hydrate, $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ is formed. Similarly the NH_3 molecules in $[\text{Co}(\text{NH}_3)_6]^{3+}$ may be replaced partly by Cl^- ions e.g., $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$

The central metal atom may be Fe^{2+} instead of Co^{3+} . The co-ordinating groups may be 6CN^- ions. We get the complex ferro-cyanide and ferricyanide ions respectively.



The original Fe^{2+} and Fe^{3+} ions with 2 and 3 positive charges respectively, after co-ordinating with 6 negatively charged CN^- ions are converted into complex ferrocyanide and ferricyanide ions with 4 and 3 negative charges respectively.

Fluoride ions may co-ordinate with a boron atom of BF_3 or a silicon atom of SiF_4 giving a borofluoride complex ion BF_4^- or a silico fluoride complex ion SiF_5^- .



In the case of salts containing several molecules of water of crystallisation, eg., $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ etc., both the cations and anions may be regarded as being co-ordinated with water molecules.

Effective atomic number :

Sidgwick suggested that metal ions will tend to accept electron pairs from donors until they have obtained a sufficient number of electrons such that the metal in the resulting complex ion has an effective atomic number of the next inert gas.

Definition

$$\left. \begin{array}{l} \text{The effective atomic} \\ \text{number (EAN) of a} \\ \text{metal in a complex} \end{array} \right\} = \left\{ \begin{array}{l} \text{Atomic number of the metal - Electrons} \\ \text{lost in ion formation + number of electrons} \\ \text{gained by co-ordination.} \end{array} \right.$$

In many cases the EAN of the metal in complex corresponds to the next heavier inert gas element.

Example :i. In $K_4[Fe(CN)_6]$

Atomic number of Fe = 26

Number of electrons lost during the formation of Fe^{2+} ionNumber of electrons gained by co-ordination = $6 \times 2 = 12$ \therefore EAN of Fe = $26 - 2 + 12 = 36 = \text{At.No. of Kr}$.ii. In $[Ni(CO)_4]$

Atomic number of Ni = 28

It is in zero oxidation state. Therefore number of electron lost = 0

Number of electrons gained by co-ordination = $4 \times 2 = 8$ \therefore EAN of Ni = $28 + 8 = 36 = \text{At.No. of Kr}$.iii. In $K_2[Cd(CN)_4]$

Atomic number of Cd = 48

Number of electrons lost during the formation of Cd^{2+} ion = 2Number of electrons gained by co-ordination = $4 \times 2 = 8$ \therefore EAN of Cd = $48 - 2 + 8 = 54 = \text{At. No. of Xe}$ **The EAN for various metals in complexes are given in Table 1.**

Metal ion	At.No.of metal	CN.	Electrons lost in ion formation	Electrons added by co-ordination	EAN
Fe^{2+}	26	6	2	12	36(Kr)
Co^{3+}	27	6	3	12	36(Kr)
Cu^+	29	4	1	8	36(Kr)
Pd^{4+}	46	6	4	12	54(Xe)
Ir^{3+}	77	6	3	12	86(Rn)
Pt^{4+}	78	6	4	12	86(Rn)

Note :

There are certain metal ions which do not obey the effective atomic number concept. E.g., In $[Fe(CN)_6]_3^-$ EAN of Fe = $26 - 3 + 12 = 35$. Which is not the atomic number of the next inert gas, viz., Kr (36).

1
UNIT - I

CO-ORDINATION CHEMISTRY - I

Introduction :

When solutions of two or more simple salts are mixed in simple molecular ratio, and the mixture of solutions is allowed to evaporate, crystals of a new compound are obtained. This new compound is known as an addition compound or a molecular compound.

Molecular compounds are classified into two types:

1. Double salts
2. Co-ordination compounds or complex compounds.

1. Double salts :

What are they? They are the molecular compounds obtained by mixing solutions of two or more simple salts, in simple molecular ratio and allowing the mixture of solutions to evaporate.

- E.g.,
- i. Mohr's salt - $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$
 - ii. Carnallite $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$.
 - iii. Potash alum - $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$.

2. Co-ordination compounds or complex compounds:

What are they? They are also molecular compounds obtained by mixing solutions of two or more simple salts in simple molecular ratio and allowing the mixture of solutions to evaporate.

- E.g.,
- i. Potassium ferrocyanide - $\text{K}_4[\text{Fe}(\text{CN})_6]$
 - ii. Diamminesilver(I) chloride - $[\text{Ag}(\text{NH}_3)_2]\text{Cl}$.
 - iii. Hexamminecobalt(III) chloride - $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$.

Comparison between double salts and co-ordination compounds :

Similarities:

- i. Both are prepared by mixing two or more simple salt solutions, in simple molecular ratio, and then, by evaporating the mixture of the solutions.
- ii. Both are addition compounds or molecular compounds.

Distinctions

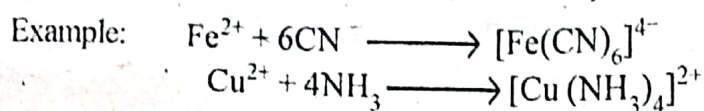
	Double salts	Co-ordination Compounds
i. Stability	Stable in solid state Break down into individual ions in solutions. E.g $\text{Fe SO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O} \rightarrow \text{Fe}^{2+} + 2\text{NH}_4^{2+} + 2\text{SO}_4^{2-} + 6\text{H}_2\text{O}$	Stable both in solid state and in solution. The complex part retains its identity in solution. E.g $\text{K}_4[\text{Fe}(\text{CN})_6] \rightarrow 4\text{K}^+ + [\text{Fe}(\text{CN})_6]^{4-}$
ii. Physical and Chemical properties	Same as the individual constituents	Completely different from those of the individual constituents

The co-ordination compounds are molecular compounds obtained by mixing solutions of two or more simple salts in simple molecular ratio and allowing the mixture of solutions to evaporate. They contain a central atom or ion, usually a metal, surrounded by a cluster of ions or molecules, bound by co-ordination bonds. They are also known as metal complexes. The complex tends to retain its identity even in solution.

Some terms used in co-ordination chemistry :

Complex ion :

Definition : A complex ion is an electrically charged radical which is formed by the union of a simple cation with one or more neutral molecules or ions.



Central ion :

Definition : In a co-ordination compound, the central metal ion which is attached to various ions or neutral molecules is called the central ion.

Example : In $[\text{Fe}(\text{CN})_6]^{4-}$, Fe^{2+} ion is the central ion. Similarly In $[\text{Cu}(\text{NH}_3)_4]^{2+}$, Cu^{+2} ion is the central ion.

Ligand:

Definition: The neutral molecules or ions (usually anions) which are attached with the central metal ion are called ligands.

Example: In the complex ion, $[\text{Fe}(\text{CN})_6]^{4-}$, Fe^{2+} ion is the central metal ion and the six CN^- ions are the ligands.

In most of the complexes a ligand acts as a donor of electrons to the central metal ion which acts as the acceptor. In a ligand the particular atom which actually donates the electron pair to the metal atom is called the donor atom.

Example: In CN^- ion, nitrogen acts as the donor atom.

Co-ordination number :

Definition: The maximum number of atoms or groups which can be co-ordination number (C.N). The co-ordinated groups are called ligands. Each metal has a fixed C.N. Co-ordination number is sometimes called Werner's co-ordination number.

Example :	Metal ion	C.N.
	$\text{Zn}^{2+}, \text{Cu}^{2+}, \text{Pt}^{2+}, \text{Cd}^{2+}, \text{Ni}^{2+}$	4
	$\text{Fe}^{3+}, \text{Fe}^{2+}, \text{Co}^{3+}, \text{Pt}^{4+}, \text{Cr}^{3+}$	6
	In $[\text{Fe}(\text{CN})_6]^{3-}$ ion, the C.N. of Fe^{3+} is	6

The co-ordination number of metals vary from 2 to 10 but the most common C.Ns are 4 and 6.

Nomenclature of Mono nuclear Complexes :

The International Union of Pure and Applied Chemists (I.U.P.A.C.) published rules for the systematic naming of co-ordination compounds in 1957, which are to be observed in naming the co-ordination compounds.

They are as follows:

- 1 In ionic complexes, the cation is named first and then the anion. Non-ionic or molecular complexes are given a one word name.
- 2 Co-ordinated groups are listed in the following order: Negative ligands, neutral ligands and then positive ligands.
- 3 If the name of the ligand ends in 'ide' it is changed into-O.

<i>Examples :</i>	Chloride	----	Chloro
	Cyanide	----	Cyano
	Oxide	----	Oxo
	Hydroxide	----	Hydroxo

If the name ends in 'ate' or 'ite' then 'e' changed into 'o'

<i>Examples :</i>	Cyanate	----	Cyanato
	Sulphate	----	Sulphato
	Sulphite	----	Sulphito
	Acetate	----	Acetato
	Carbonate	----	Carbonato
	Oxalate	----	Oxalato

4. Neutral ligands are named as the molecule. But water is named as aquo and ammonia as ammine or amino.

5. Positive ligands end in 'ium'.

Example: Hydrazinium $\text{H}_2\text{N} - \text{NH}_3^+$

6. If the complex ion is a cation, the central atom is referred to by its usual name. If it is an anion the name of the central ion ends in ate.

Neutral complexes have no special ending.

7. The ligands so named are followed by the name of central atom and oxidation state of the central ion is indicated by a Roman numeral in brackets following its name.

8. If ligands have simple names such as chloro, bromo, nitro, oxalato etc., their number is indicated by prefixes such as di, tri, tetra, penta etc. If the ligands have complex names their number is indicated by prefixes such as bis, tris, tetrakis etc.

9. If the complex contains more than one negative ligand they are named in the increasing order of increasing order or electronegativity and also in the order of increasing complexity. When the two ligands have the same number of atoms, the order is that decreasing atomic number of the central-atomic species in the ligand.

Example : CrO_4^{2-} first and SO_4^{2-} next.

Neutral ligands are named in the order H_2O (aquo), NH_3 (ammine).

Neutral organic ligands are named in alphabetical order.

Isomerism in complexes

Molecules or ions having the same chemical composition but different structures are called isomers and the phenomenon is known as isomerism. Co-ordination compounds exhibit different types of isomerism as follows ;

1. Structural isomerism
2. Stereoisomerism

Low

L Structural isomerism in 4 and 6 co-ordinate complexes :

I. *Ionization isomerism :*

Compounds which have the same composition but yield different ions in solution are called ionization isomers. This type of isomerism is due to the exchange of groups between the complex ion and the ions outside it.

Example :

$[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$ gives SO_4^{2-} ions and

$[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}_2$ gives Br^- ions

Other examples :

$[\text{Pt}(\text{NH}_3)_4\text{Cl}_2]\text{Br}_2$ and $[\text{Pt}(\text{NH}_3)_4\text{Br}_2]\text{Cl}_2$

$[\text{Co}(\text{NH}_3)_5\text{NO}_3]\text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{NO}_2$

2. Hydration isomerism :

These isomers differ in the number of water molecules attached to the metal ion as ligands in the co-ordination sphere.

Examples :

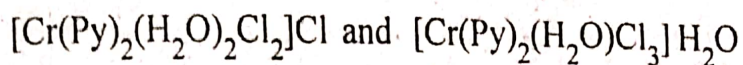
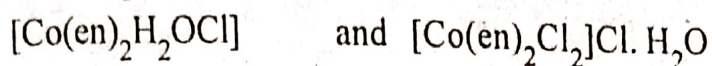
$[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ Violet. Three ionic chlorines.

$[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2\text{H}_2\text{O}$ Green. Two ionic chlorines.

$[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl}2\text{H}_2\text{O}$ Darkgreen. One ionic chlorine.

The complex $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ exist in three isomeric forms as given above, which differ in the position of water molecules. These isomers differ in physical and chemical properties.

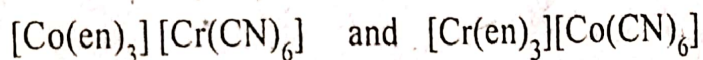
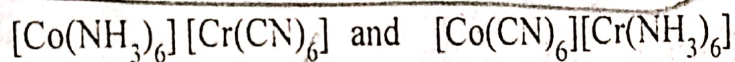
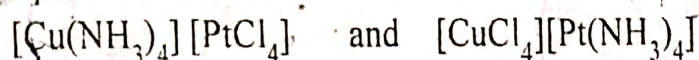
Other examples :



3. Co-ordination isomerism :

This type of isomerism is found in compounds where both anion and cation are co-ordinated. This is caused by the interchange of ligands between the complex ions.

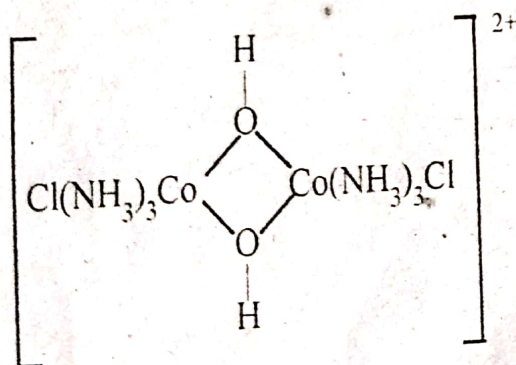
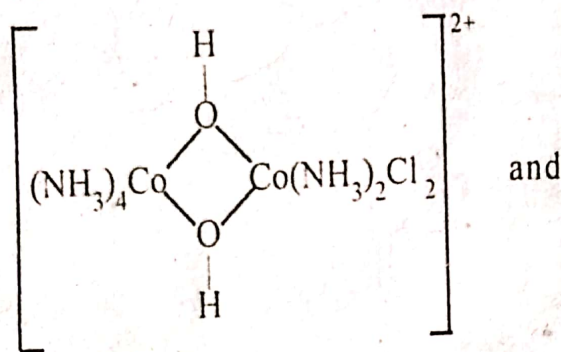
Examples :



4. Co-ordination position isomerism :

This type of isomerism is found in bridged complex. This is caused by a difference of placement of ligands.

Examples :

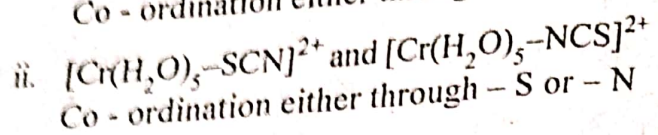
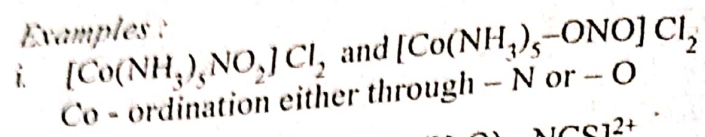


5. Linkage isomerism :

Linkage isomerism arises when a monodentate ligand has two different

donor atoms available for co-ordination. The linkage between the metal and ligand in one isomer is through one ligand atom and that of its isomer is through another.

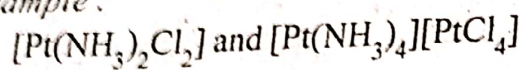
Examples :



6. Polymerization isomerism :

Polymerization isomerism is exhibited by compounds which have the same stoichiometric composition but whose molecular compositions are multiples of the simple stoichiometric arrangement.

Example :

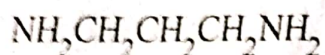


7. Ligand isomerism :

Some ligands themselves are capable of existing as isomers. E.g., diamino propane can exist as both 1, 2 - diamino propane (pn) and 1, 3 - diamino propane also called trimethylene diamine (tn).



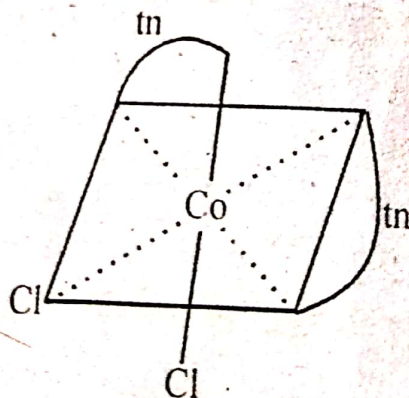
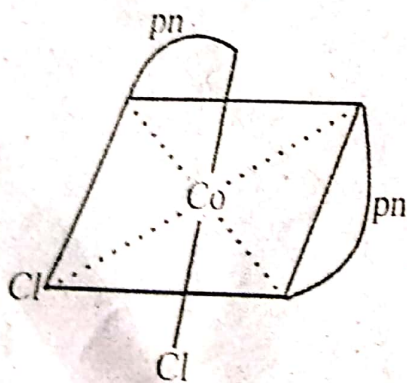
1, 2 - diamino propane (pn)

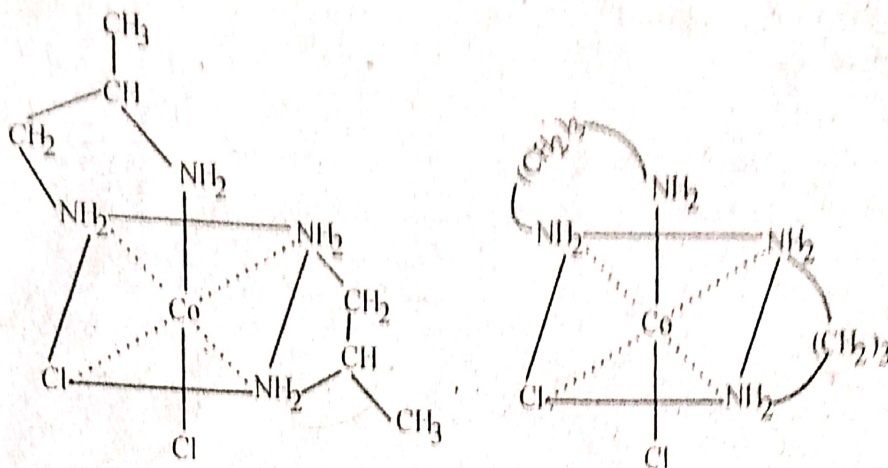


1, 3 - diamino propane or trimethylene diamine (tn)

When pn and tn are present in different complexes, then such complexes would be isomers. This phenomenon is called ligand isomerism.

E.g., $[\text{Co}(\text{pn})_2\text{Cl}_2]^+$ and $[\text{Co}(\text{tn})_2\text{Cl}_2]^+$.





II. Stereoisomerisms :

Molecules of ions having same molecular formula same structural formula but different configurations are called stereoisomers. The phenomenon is called stereoisomerism. Stereoisomerism is of two types

i. Geometrical isomerism

ii. Optical isomerism

Geometrical isomerism or cis - trans isomerism :

Geometrical isomerism is a phenomenon exhibited by two compounds having same molecular formula, same structural formula but different configurations. In these compounds similar atoms or groups are placed either adjacent to each other or opposite to each other. If similar atoms or groups (ligands) are placed adjacent to each other then they are known as cis compounds. If similar atoms or groups are placed opposite to each other then they are known as trans - compounds.

Cis - trans isomerism is not possible for complexes of C.N. 2 or 3. In these systems all co - ordinate positions are adjacent to one another.

Complexes having central metal atom with co - ordination number 4 may be either tetrahedral or square planar. Geometrical isomerism cannot arise in tetrahedral complexes (CN = 4) because in this geometry all the ligands are cis to each other. Each ligand is equidistant from the other three ligands and all the bond angles are same ($109^{\circ}28'$) Because of such an arrangement all ligands are cis to each other. So, geometrical isomerism is not possible in tetrahedral complexes.

Thus this isomerism is found in square planar (CN = 4) and octahedral (CN = 6) complexes only.

Geometrical isomerism in 4 co-ordinate (square planar) complexes :

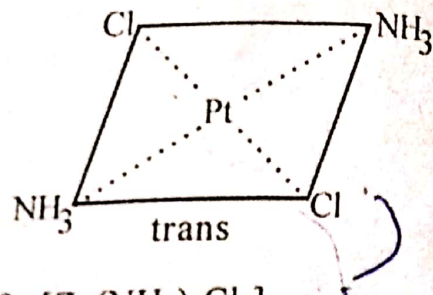
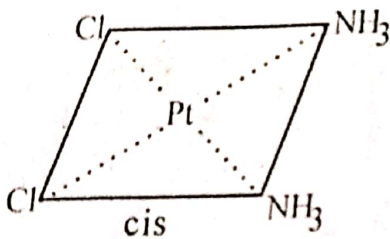
Examples :

1. $[Ma_4]$, $[Ma_3b]$, $[Mab_3]$ type complexes do not show geometrical isomerism since very conceivable spatial arrangement of ligands around the metal ion is equivalent. Here M = metal ion, a and b are monodentate ligands.

① $[Ma_2b_2]$, $[Ma_3bc]$ and $[Mabcd]$ (a, b, c and d are monodentate ligand) exhibit cis - trans isomerism.

$[Ma_2b_2]$ type complexes :

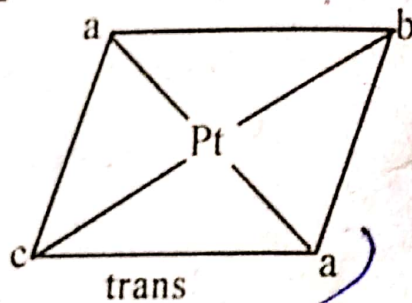
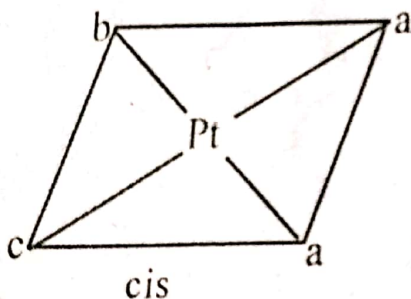
Examples : $[Pt(NH_3)_2Cl_2]$



Other examples : $[Pd(NH_3)_2(NO_2)_2]$; $[Zn(NH_3)_2Cl_2]$

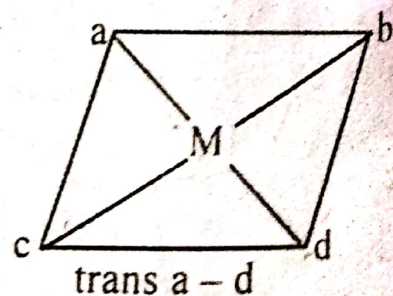
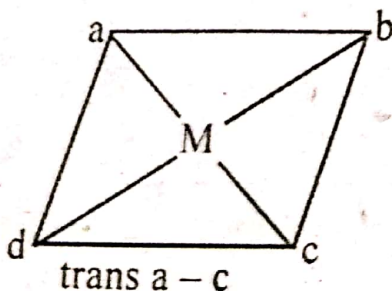
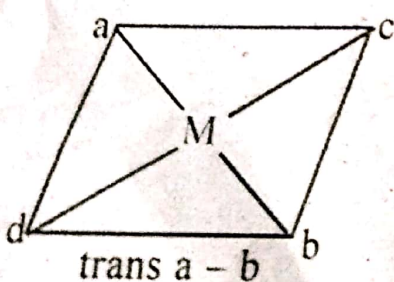
② $[Ma_2bc]$ type complexes :

Examples : $[Pt a_2bc]$. Here 'a' is a neutral ligand like NH_3 and H_2O . b and c are ionic ligands like Cl^- , Br^- , NO_2^- , SCN^- .

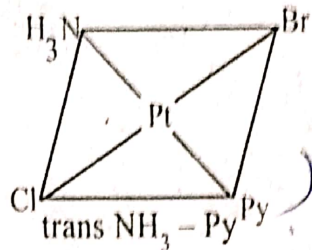
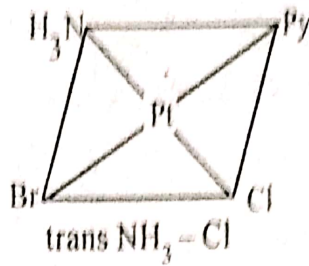
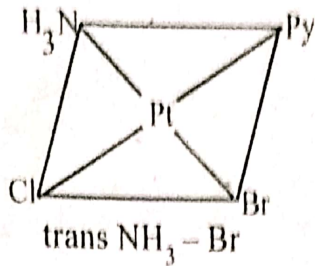


3. $[Mabcd]$ types complexes :

These complexes exist in three isomeric forms. The possible isomers are obtained by selection on group. 'a' and seeing how many different group can be placed trans to 'a'.



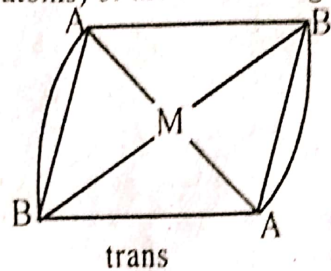
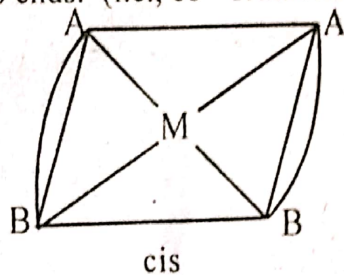
Example : $[\text{Pt}(\text{NH}_3)(\text{Py})\text{ClBr}]$



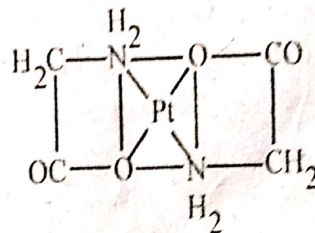
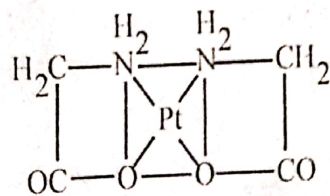
Other Example : $[\text{Pt}(\text{NH}_3)(\text{NO}_2)(\text{Py})(\text{NH}_2\text{OH})]^+$ ion,
 $[\text{Pt}(\text{C}_2\text{H}_4)(\text{NH}_3)\text{ClBr}]$

4. $[\text{M}(\text{AB})_2]$ type complexes :

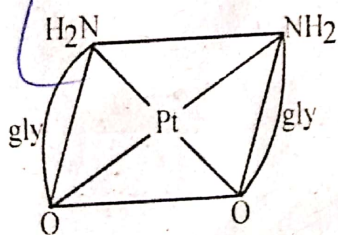
M = metal ion. AB = un - symmetrical bidentate ligand. A and B are the two ends. (i.e., co - ordination atoms) of the bidentate ligand AB .



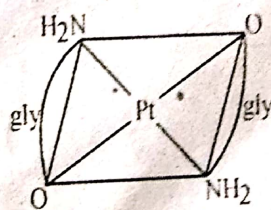
Example : $[\text{Pt}(\text{gly})_2]$



(or)



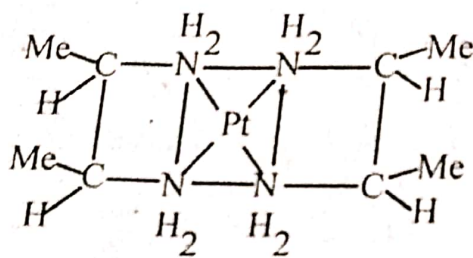
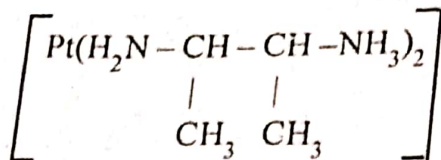
(or)



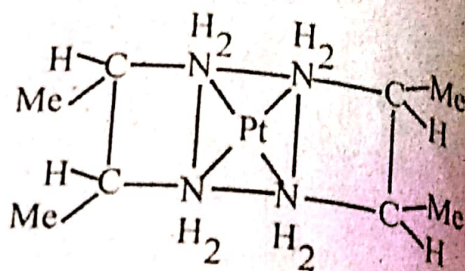
cis - Diglycinato platinum (II) trans - Diglycinato platinum (II)

5. $[M(AA)_2]$ type complexes :
AA = Symmetrical bidentate ligand

Example :



cis

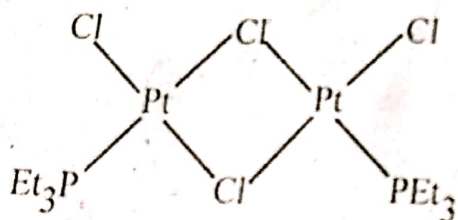


trans

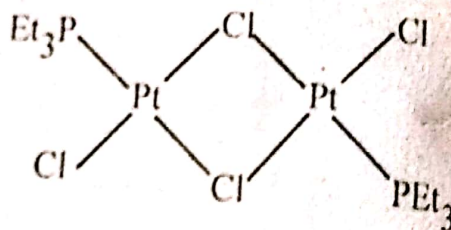
Other Examples : $[\text{Ni}(\text{en})_2]^{2+}$

6. Bridged bi-nuclear planar complexes of $M_2a_2b_4$ type :

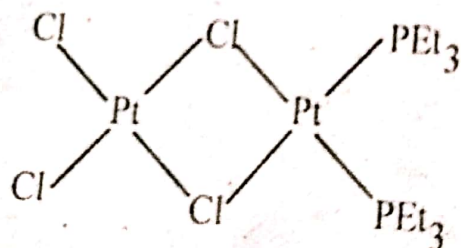
In bridged binuclear square complexes cis - trans isomer as well as the unsymmetrical isomers possible.



cis



trans

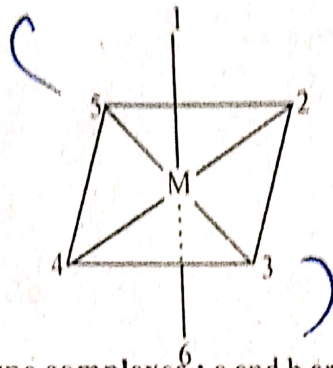


unsymmetrical

PEt_3 = triethyl phosphine

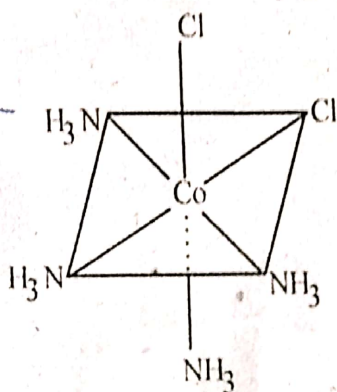
Geometrical isomerism in 6-coordinate (octahedral) complexes :

The arrangement of six ligands in a regular octahedron around the central metal ion M is shown below :

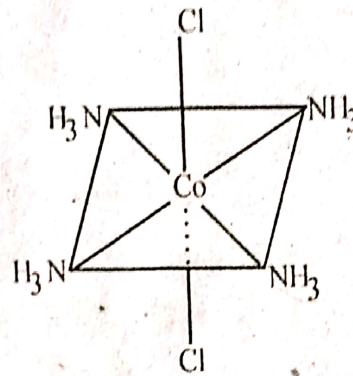


1. $[Ma_4b_2]$ type complexes : a and b are monodentate ligands.

Example : $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ ion



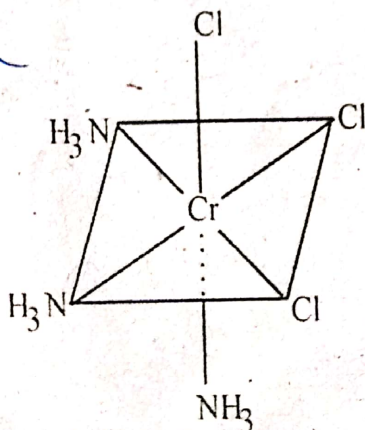
cis (1, 2, 3 - isomer)



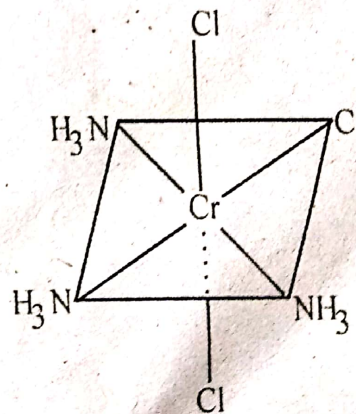
trans (1, 2, 6 - isomer)

2. $[Ma_3b_3]$ type complexes :

Example : $[\text{Cr}(\text{NH}_3)_3\text{Cl}_3]$; $[\text{Rh}(\text{Py})_3\text{Cl}_3]$



cis (1, 2, 3 - isomer)



trans (1, 2, 6 - isomer)

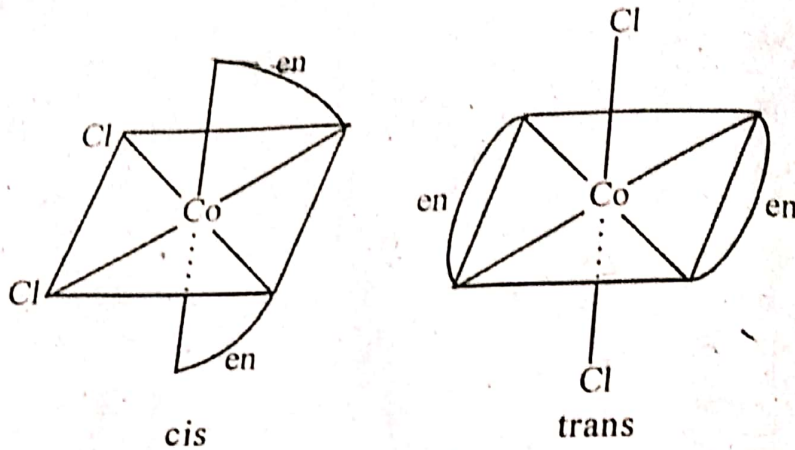
3. **[M abcdef] type complexes :**

This type of octahedral complexes can exist in 15 different geometrical isomers. The only compound of this type is $[\text{Pt}(\text{Py})(\text{NH}_3)(\text{NO}_2)\text{ClBr}]$.

4. **[M(AA)₂a₂] type complexes :**

(AA) = Symmetrical bidentate ligand. a = Monodentate ligand.

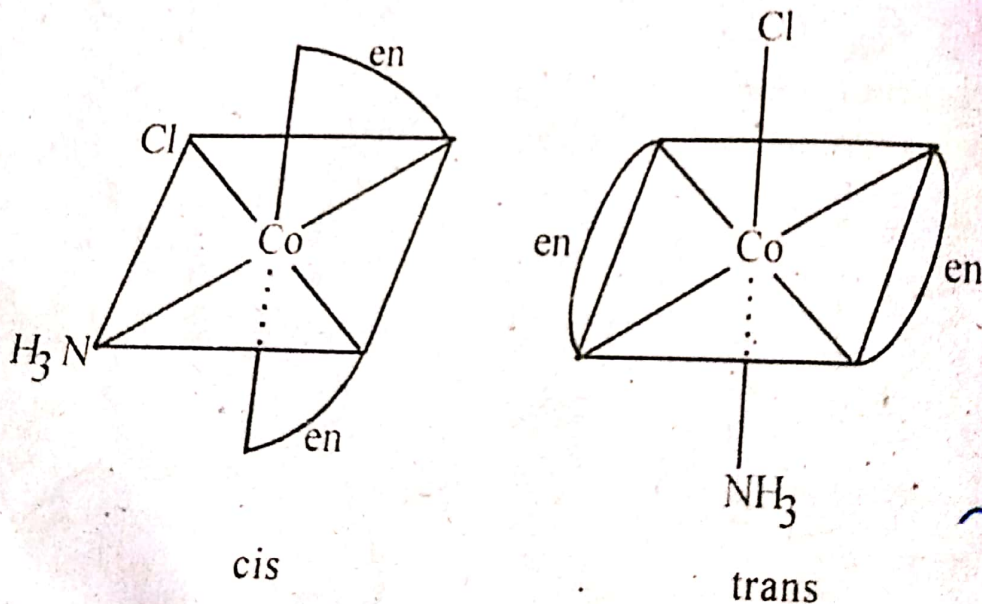
Example : $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ ion.



Other examples : $[\text{Co}(\text{en})_2(\text{NO}_3)_2]^+$ ion, $[\text{Cr}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O}_2)]^-$ ion

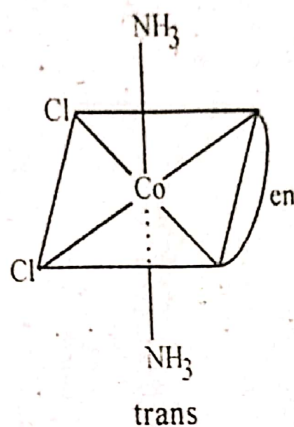
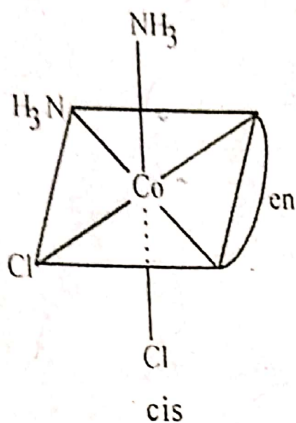
5. **[M(AA)₂ab] type complexes :**

Example: $[\text{Co}(\text{en})_2(\text{NH}_3)\text{Cl}]^+$ ion



$[M(AA)_2a_2b_2]$ type complexes :

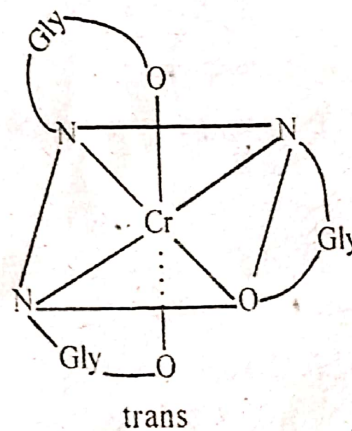
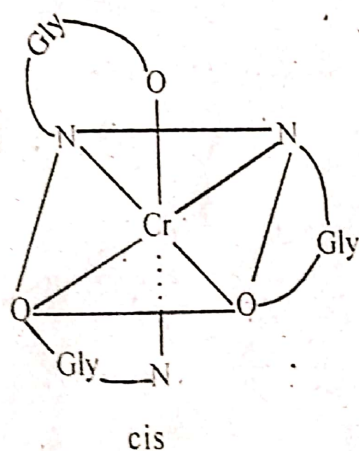
Example : $[Co(en)(NH_3)_2Cl_2]^+$ ion



7. $[M(AB)_3]$ type complexes :

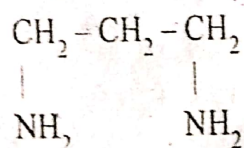
AB = unsymmetrical bidentate ligand. A and B represent the coordinating atoms of the ligand.

Example : $[Cr(gly)_3]$

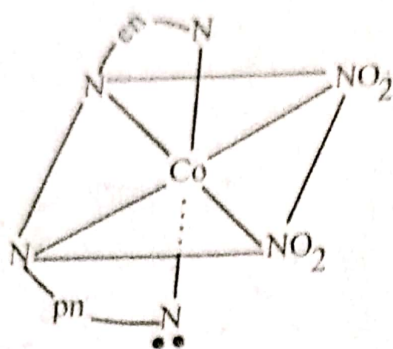


8. Octahedral complexes containing optically active bidentate ligands :

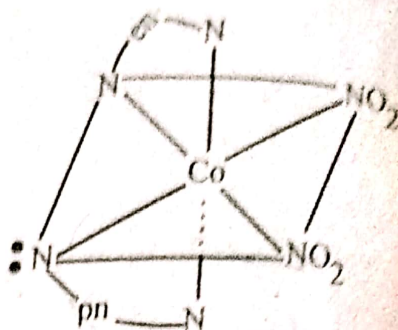
Example : $[Co(en)(Pn)(NO_2)_2]^+$ ion, pn = 1, 2 diaminopropane



The above complex ion exists in four geometrical forms two are cis and two are trans.



cis



trans

Methods for distinguishing cis and trans isomers :

1. **Dipole moment studies :**
Compounds with $\mu = 0$ are trans isomers. Compounds with $\mu = 8$ to 12 debye are cis isomers.
2. **IR studies :**
Trans compounds do not show any bands cis compounds show a number of bands due to stretching vibrations.
3. **Optical activity studies :**
Trans compounds are optically inactive, cis compounds are optically active.
4. **Chelation studies :**
The isomer which reacts with chelating reagents or which is formed a chelate precursor is cis. The isomer, which does not do, so is trans.

Resolution of Racemic Mixtures

Resolution

Definition : "The separation of a racemic mixture into its enantiomers (dextro-and laevo-components) is termed as resolution".

Explanation : Any attempt to prepare an optically active form of a compound ends up in a racemic mixture only. So they have to be separated into *d* and *l* forms. The process of such separation is called **resolution**.